Radiolarians as tracers for provenance of gravels in Lower Cretaceous molasse (Outer Zone of SW Japan)

Keisuke ISHIDA
Laboratory of Geology, Faculty of Integrated Arts and Sciences, University of Tokushima
1-1 Minamijosanjima, Tokushima 770-8502 (Japan)
ishidak@ias.tokushima-u.ac.jp

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Provenance,
conglomerate,
molasse,
radiolarian dating,
Jurassic accretionary complex,
Cretaceous,
SW Japan.

ABSTRACT
This paper discusses the results and the recent status of the study by radiolarians as tracers for erosional events, especially for those of Jurassic and pre-Jurassic accretionary complexes in the Outer Zone of SW Japan. As a test case to clarify the provenance of radiolarian-bearing gravels in conglomerates, the author reviewed the work previously done to trace the source rocks within oceanic-plate stratigraphy successions from monomictic chert-pebble conglomerates of the Lower Cretaceous Ryoseki-Monobegawa group. The group is a molasse typical of paralic sedimentary facies in the Outer Zone of SW Japan.

MOTS CLÉS
Provenance,
conglomérat,
molasse,
datation par radiolaires,
complexes d'accrétion jurassiques,
Crétacé,
SW Japon.

RÉSUMÉ
De l'utilisation des radiolaires comme indicateurs de provenance des graviers dans les molasses crétacées inférieures (zones externes du SW Japon).
Le présent article discute des implications qu'a l'utilisation récente des radiolaires comme indicateurs d'événements érosifs, en particulier de ceux de complexes d'accrétion jurassiques et anté-jurassiques au SW Japon. Comme étude de cas pour éclairer la provenance de graviers à radiolaires des conglomérats, l'auteur effectue une revue des séries stratigraphiques synthétiques à partir des conglomérats monogéniques à galets de cherts du groupe Ryoseki-Monobegawa du Crétacé inférieur. Ce groupe molassique est de faciès sédimentaire paralique typique des zones externes du SW Japon.

INTRODUCTION

In the last two decades, radiolarian researchers in Japan made an effort to clarify the Permian, Triassic and Jurassic biostratigraphy, and established many radiolarian biostratigraphic zones (e.g., Ishiga 1986, 1990; Matsuoka & Yao 1986; Yao 1990; Matsuoka 1995 etc.) within accretionary complexes (AC; Taira *et al.* 1981). They analyzed bed by bed the faunas from blocks of pelagic sediments in melanges and olistostromes. It contributed to reconstruct the oceanic plate stratigraphy (OPS) from these tectonically disrupted sedimentary rocks (e.g., Matsuoka 1984; Ishida 1987; Hada & Kurimoto 1990; Isozaki 1997a), as well as to distinguish geologic units and to clarify their spatial distribution (Mizutani 1995).

Radiolarians are important indexes for the Paleozoic and the Mesozoic. Their size averages 10^{-1} mm. They are therefore small enough to be reworked as an inclusion into clasts of various size and even in sand grains. This property is effective to analyse erosional events. Radiolarians are available for identifying source rocks of clastics.

The "clastic approach" of radiolarian dating appears particularly appropriate for chert-bearing terrane analysis of the Canadian Cordillera (Cordey 1992). In case of California Coast Ranges, analysis of radiolarian chert-pebbles is more effective than sandstone component not only for the provenancial study but also for clarifying the tectonic movement along the transform fault (Seiders & Blome 1984, 1988).

This paper deals with erosional events following the setting of accretionary complexes. This is one test case in the reconstruction of OPS from the gravels and clasts in the monomictic conglomerates. In this case, radiolarians in gravels are used as tracers for erosional events. This type of test will become a great help to study the orogenic and/or erosional events in the marginal area of the Late Mesozoic East Asian continent.

GEOLOGY OF SW JAPAN

With respect of the continuity of the pre-Neogene orogenic units and ACs, at least the southwest side of the Tanakura Tectonic Line is regarded as SW Japan. The post-Neogene geological province of SW Japan is subdivided into the Inner Zone on the continental side and the Outer Zone on the trench side by the Median Tectonic Line (MTL). Based on a paleobiogeographical study, the left-lateral slip movement along the MTL is regarded to reach about 1500 km after the Early Cretaceous time (Tazawa 1993). Concerning the pre-Neogene geology, nappes and klippes of the Permo-Triassic orogenic units and Jurassic ACs are distributed in the Inner and the Outer zones of SW Japan (Fig. 1). The Inner Zone of SW Japan is composed of the Hida, Marginal Hida, Akiyoshi, Sangun, Maizuru, Ultra-Tamba, and the Mino-Tamba belts from the north to the south.

The Hida Belt is mainly composed of gneisses with intrusion of Permian-Jurassic granites. The Tetori group of the Middle Jurassic-Lower Cretaceous shallow-marine and non-marine formations unconformably overlies these gneisses and granites. The Hida Belt is situated in the most continental side of SW Japan, and is supposed to thrust on the Akiyoshi, Sangun, Maizuru and the Ultra-Tamba belts.

The Marginal Hida Belt is situated between the Hida and the Mino-Tamba belts. It is supposed to thrust upon the Mino-Tamba Belts together with the Hida Belt. The Marginal Hida Belt is composed of Paleozoic complex with Triassic formation that are unconformably overlain by the Lower-Middle Jurassic Kuruma group. The Paleozoic complexes appear to be serpentinite melanges that include blocks of glaucophane schists, amphibolites, Early-Late Paleozoic clastic sediments with limestones.

The Akiyoshi Belt is composed of the Middle-Late Paleozoic ACs and the Mesozoic cover formations. The Late Paleozoic ACs contain large blocks of Carboniferous and Permian limestones with basalts as well as blocks of Permian cherts, mudstones and sandstones. The Mesozoic shallow-marine and brackish cover formations are the Triassic Natiwa group and the Jurassic Yamaoku formations.

The Sangun Belt is mainly composed of 180-230 Ma glaucophane schists and slates that are

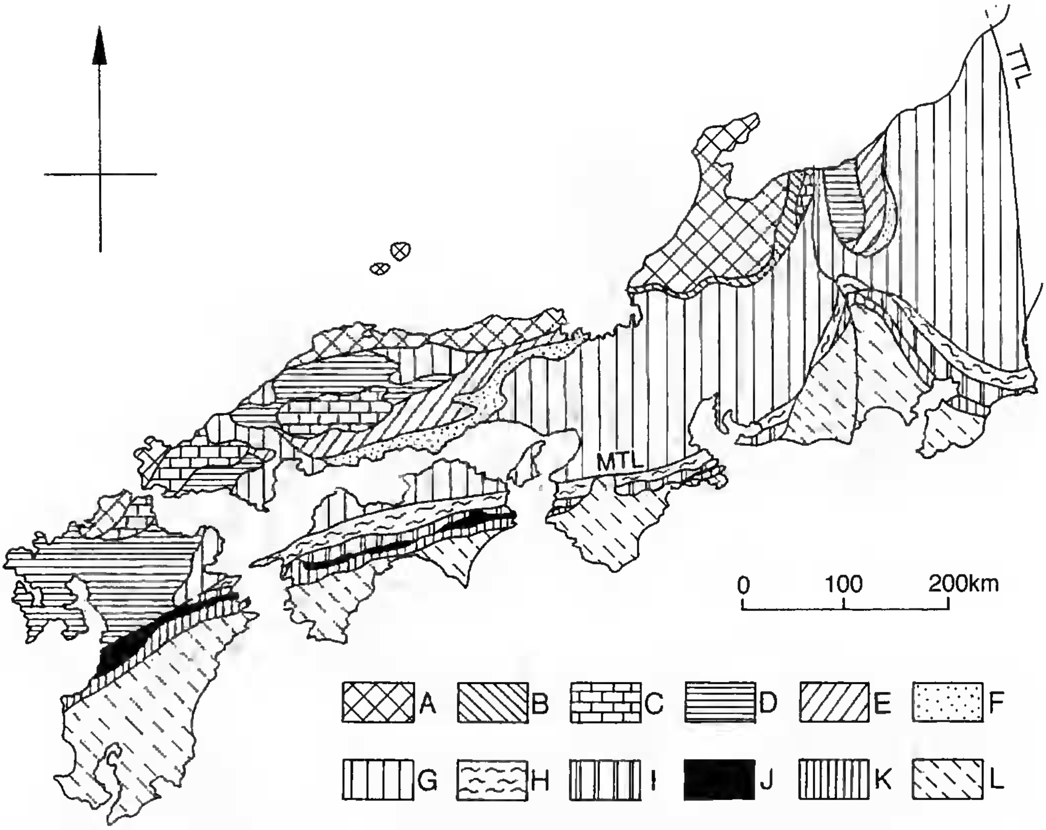

FIG. 1. — Zonal distribution of pre-Neogene orogenic units and accretionary complexes in SW Japan. **A**, Hida; **B**, Marginal Hida; **C**, Akiyoshi; **D**, Sangun; **E**, Maizuru; **F**, Ultra-Tamba; **G**, Mino-Tamba belts of the Inner Zone; **H**, Sambagawa-Mikabu; **I**, North Chichibu; **J**, Kurosegawa; **K**, South Chichibu belts; **L**, Shimanto Superbelts of the Outer Zone. **MTL**, Median Tectonic Line; **TTL**, Tanakura Tectonic Line.

originated from mudstones, sandstones, and basalts with cherts of the Late Permian ACs.

The Maizuru Belt is composed of Paleozoic basic rocks (Yakuno ophiolite) and Middle-Late Permian slope basin deposits (Maizuru group) that are unconformably overlain by the Lower-Middle Triassic Yakuno group.

The Ultra-Tamba Belt is subdivided into three nappes. The highest nappe of the UT3 is composed of Upper Permian mudstones and greenstones with cherts and Upper Carboniferous limestones. Intermediate nappe of the UT2 is composed of Upper Permian siliceous mudstones with Lower-Middle Permian bedded cherts. The lowest nappe of the UT1 is composed of Middle-Late Permian mudstones and greenish sandstones. The Permian formations of the UT1 are unconformably overlain by the non-marine Lower Cretaceous Sasayama group.

The Mino-Tamba Belt is composed mainly of the Early Jurassic-earliest Cretaceous ACs that are intruded by the Late Cretaceous Ryoke granites. They are unconformably overlain by the Late Cretaceous volcano-clastic formations (Nohi rhyolites) and the Paleogene non-marine conglomerates. The Early Jurassic-earliest Cretaceous ACs are subdivided into several tectonic units. They are composed of Permian, Middle-Upper Triassic and Lower-Middle Jurassic cherts with Early Triassic siliceous claystones, Jurassic-earliest Cretaceous mudstones and turbidites. These ACs also contain blocks of Upper Paleozoic limestones and basaltic greenstones.

The Outer Zone of SW Japan is composed of the Sambagawa-Mikabu, North Chichibu, Kurosegawa, South Chichibu belts and the Shimanto Superbelt from the north to the south.

The Sambagawa-Mikabu Belt is composed of the Sambagawa crystalline schists and the Mikabu greenstones. This belt is supposed to consist of the Early Jurassic-Early Cretaceous ACs. Multiple nappe structure is characteristic in this belt. The Sambagawa crystalline schists are composed of basic and pelitic schists with quartz and psammitic schists. Some of the intetcalated calcareous schists in the basic schists are originated from the Upper Triassic limestones (Suyari *et al.* 1980a). The Mikabu greenstones are composed of low-metamorphosed gabbros, dolerites, pillow basalts and basaltic hyaloclastites with Upper Jurassic cherts (Faure *et al.* 1991), mudstones and Upper Triassic limestones. They experienced H-P/L-T metamorphism during the Cretaceous. Metamorphic grade is higher in the northern nappes.

The geometry of the Kurosegawa Belt with respect to the Jurassic AC is not yet settled sufficiently. However, after the Early Cretaceous time, the non-metamorphosed Jurassic AC and the pre-Jurassic AC of the Outer Zone of SW Japan are distributed in a terrane that is called the Chichibu Superterrane. The Chichibu Superterrane is subdivided into the pre-Jurassic AC of the Kurosegawa Belt, and the Jurassic AC of the North Chichibu and the South Chichibu belts.

The Kurosegawa Belt is situated in the central part of the Chichibu Superterrane, and is composed of the Paleozoic AC that is unconformably overlain by the Mesozoic cover formations. This belt is subdivided into the north and the south units. In the south unit, pre-Jurassic AC is composed of Petmian and Middle Paleozoic formations that are unconformably overlain by shallow marine and paralic formations of the Middle-Upper Triassic *Daonella-Monotis* beds, Middle-Upper Jurassic Torinosu group and the Lower Cretaceous Takegatani group. The Permian formations are melanges and slope basin facies. The Middle Paleozoic fromations appears with serpentinites as lenticular bodies that are composed of gneisses, granites and the Silurian limestones. The north unit is composed of the Permian AC that is unconformably overlain by the Lower Cretaceous paralic formations of the Ryoseki-Monobegawa group. The north unit lacks the Middle Paleozoic formations and the Triassic-Jurassic cover formations.

The North Chichibu Belt (NCB) is distributed in the north side of the Chichibu Superterrane. The NCB is composed of latest Triassic-Middle Jurassic ACs that consist of Permian, Middle-Upper Triassic and Lower Jurassic cherts with the Early Triassic siliceous claystones, Lower-Middle Jurassic mudstones and turbidites. These ACs also contain blocks of the Upper Paleozoic limestones and basaltic greenstones.

The South Chichibu Belt (SCB) is composed of Middle Jurassic-earliest Cretaceous ACs (Nakagawa group) and the Late Jurassic-Early Cretaceous slope basin formations of the Torinosu group. The Middle Jurassic-earliest Cretaceous ACs are subdivided into several tectonic units that have the accretion polarity rejuvenating from the north to the south. They are composed of Permian, Middle-Upper Triassic and Lower-Middle Jurassic cherts with the Early Triassic siliceous claystones, Middle Jurassic-earliest Cretaceous mudstones and turbidite sandstones. These ACs also contain Upper Paleozoic limestones and basaltic greenstones.

The Shimanto Superbelt is subdivided into the North Shimanto Belt (NSB) and the South Shimanto Belt (SSB). The NSB is composed of late Early-Late Cretaceous ACs and slope basin formations. These ACs contain the Lower-Upper Cretaceous cherts, and the Izuhara and Hayama slope basin formations contain olistoliths of the Triassic limestones from the SCB. The SSB is composed of the Paleogene-Miocene ACs and the slope-basin formations.

GEOLOGICAL SETTING

A nappe model of the SW Japan was proposed when the recent radiolarian works in Japan has started (Faure 1983a, b). At first, the Kurosegawa Belt was proposed to be a lower unit as a remnant of the subducted microcontinent (Faure 1985; Caridroit & Charvet 1986). In comparison with the geology of the Inner Zone of SW Japan, the Kurosegawa Belt was proposed to be a klippe above the Chichibu Klippe (Isozaki *et al.* 1992). According to Suzuki & Itaya (1994), the

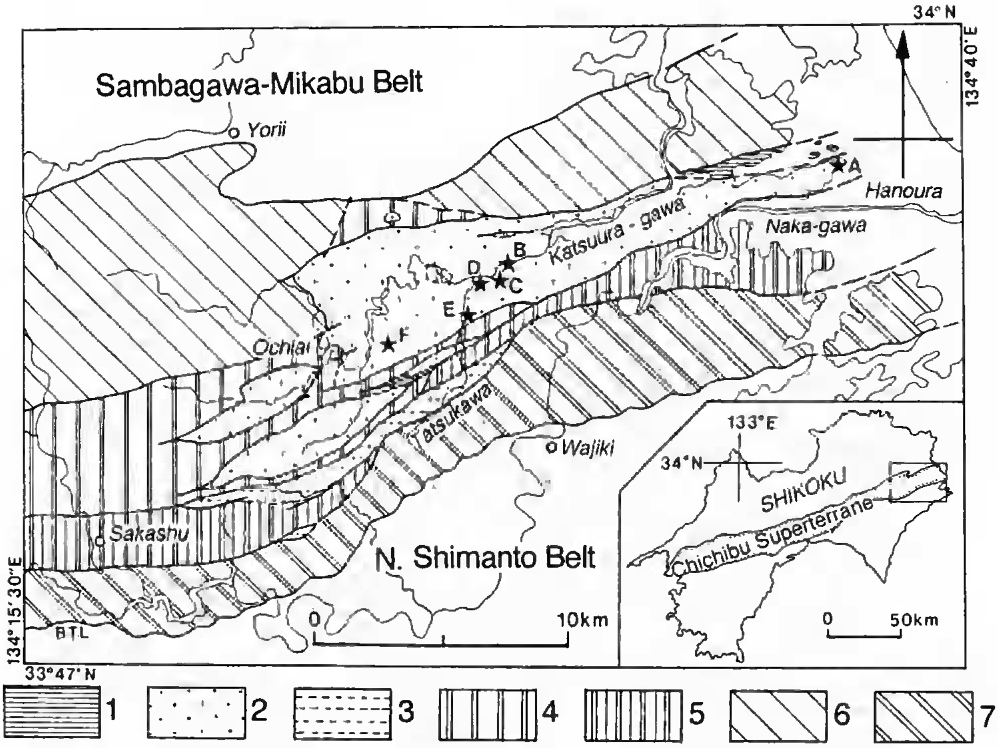

FIG. 2. — Geological outline map of the Chichibu Superterrane. **1**, Sotoizumi group (Upper Cretaceous slope basin sediments); **2**, Ryoseki-Monobegawa group (Lower Cretaceous paralic sediments); **3**, Takegatani group (Lower Cretaceous shallow marine sediments); **4**, north unit of the Kurosegawa Belt (Permian accretionary complex); **5**, south unit of the Kurosegawa Belt (Permian accretionary complex with Middle Paleozoic blocks and Triassic-Jurassic cover formations); **6**, North Chichibu Belt (Lower-Middle Jurassic accretionary complex); **7**, South Chichibu Belt (Middle Jurassic-Early Cretaceous accretionary complex).

K-Ar ages of the pre-Jurassic AC in the Kurosegawa Belt are Late Triassic to Early Jurassic (194-225 Ma). The K-Ar ages of the Jurassic AC in the North Chichibu Belt are Middle Jurassic to earliest Cretaceous.

The Ryoseki-Monobegawa group in the Outer Zone of SW Japan is characteristic of paralic facies of the Early Cretaceous age (Tashiro 1986; Tashiro & Kozai 1991; Kozai 1996; Ishida *et al.* 1992, 1996). The group unconformably overlies pre-Jurassic (Permian) melanges of the north unit of the Kurosegawa Belt (Ishida *et al.* 1992). The Kurosegawa Belt is subdivided into the north and the south units. They are situated between the Jurassic AC of the North and the South Chichibu belts (Fig. 2). In the south unit, pre-Jurassic AC with blocks of gneisses, granites and Silurian limestones is unconformably overlain by the Triassic shallow-marine formations (Sakashu unconformity: Ichikawa *et al.* 1953). Thus, thin shallow-marine Triassic and Jurassic formations overlie the Paleozoic complexes in the South Kurosegawa unit, whereas they never distribute in the north unit. The Ryoseki-Monobegawa group and the equivalent Takegatani group unconformably overlie both units of the Kurosegawa Belt. The group is composed of brackish conglomerates and shallow-marine sediments. They yield autochthonous Barremian mollusks (Matsukawa & Eto 1987).

The Lower Cretaceous formations of the Ryoseki-Monobegawa group are composed mainly of conglomerates, sandstones and mudstones with seams of tuffs, limestones and coals (Fig. 3). In East Shikoku, the group is subdivided into the Tatsukawa, Lower and Upper Hanoura, Hoji and Fujikawa formations (Ishida *et al.* 1992, 1996). These formations yield

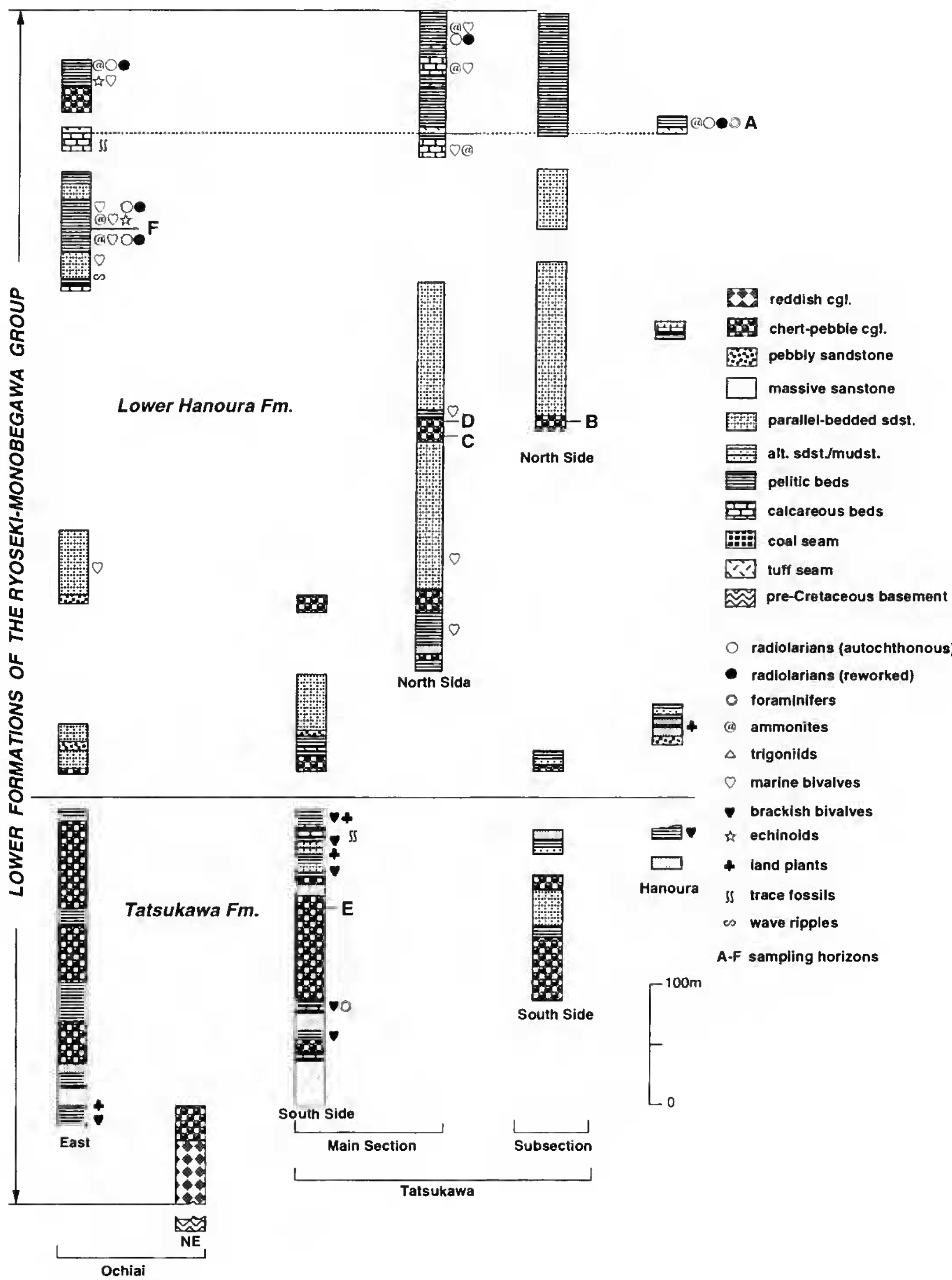

FIG. 3. — Stratigraphic columns of the lower formations of the Ryoseki-Monobegawa group in East Shikoku.

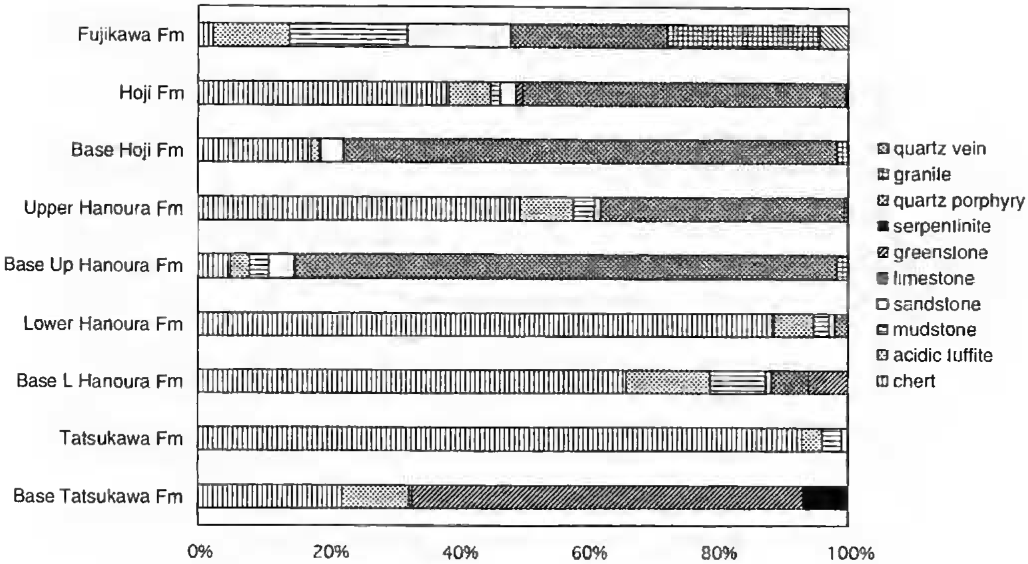

FIG. 4. — Composition and vertical change of gravels in the Ryoseki-Monobegawa group, East Shikoku.

autochthonous ammonites, bivalves, echinoids, foraminifers and radiolarians with allochthonous plants, non-marine bivalves and dinosaur teeth. They indicate Barremian to Albian ages. The radiolarian zonation of the Ryoseki-Monobegawa group is subdivided into the *Archaeodictyomitra pseudoscalaris* (Barremian), *Stichomitra communis* (upper Aptian) and *Pseudodictyomitra pentacolaensis* (middle Albian) assemblage zones in ascending order (Ishida & Hashimoto 1991a). These zones are calibrated by co-occurring ammonites. These formations form sedimentary cycles that are characterized by upward thinning and fining sequences under the effect of transgressive events. Growth of the deltaic fan is synchronous with the eustatic change. The conglomerates are more than 100 m thick, and are frequently intercalated in many horizons (Fig. 3).

Characteristics of the conglomerates, especially the size, roundness, lithology and sorting of the gravels differ in horizons. Basal conglomerate of the group is characterized by basaltic greenstone gravels and serpentinite blocks that are interpreted as the result of debris flows. Round gravels of quartz-porphyry and fine granite increase in the upper horizons, especially above the Upper Hanoura formations. In the upper part of the Tatsukawa formation and the Lower Hanoura formation, there are many chert-pebble conglomerate beds of monomictic origin (Fig. 4). The chert-pebble conglomerates are composed of round chert pebbles of a few cm in diameter that occupy more than 90% of the gravels (Fig. 4). They are well sorted, and clast-supported. For this study, the author studied these monomictic chert-pebble conglomerates with special respect to reconstruct the provenancial OPS, and extracted radiolarians from chert pebbles and mudstone clasts.

PREPARATION AND PROCESSING OF SAMPLES

This study needs some information about OPS of sedimentary basements and/or terranes of origin from radiolarian-bearing gravels in monomictic conglomerates. For this purpose, it is necessary to clarify the relationship between the lithology of gravels and their radiolarian ages. Particularly, reconstructing the OPS of terranes from gravels in monomictic conglomerates requires to be able to distinguish the lithology of gravels, whether they are of pelagic or continental origin, as well as to determine their radio-

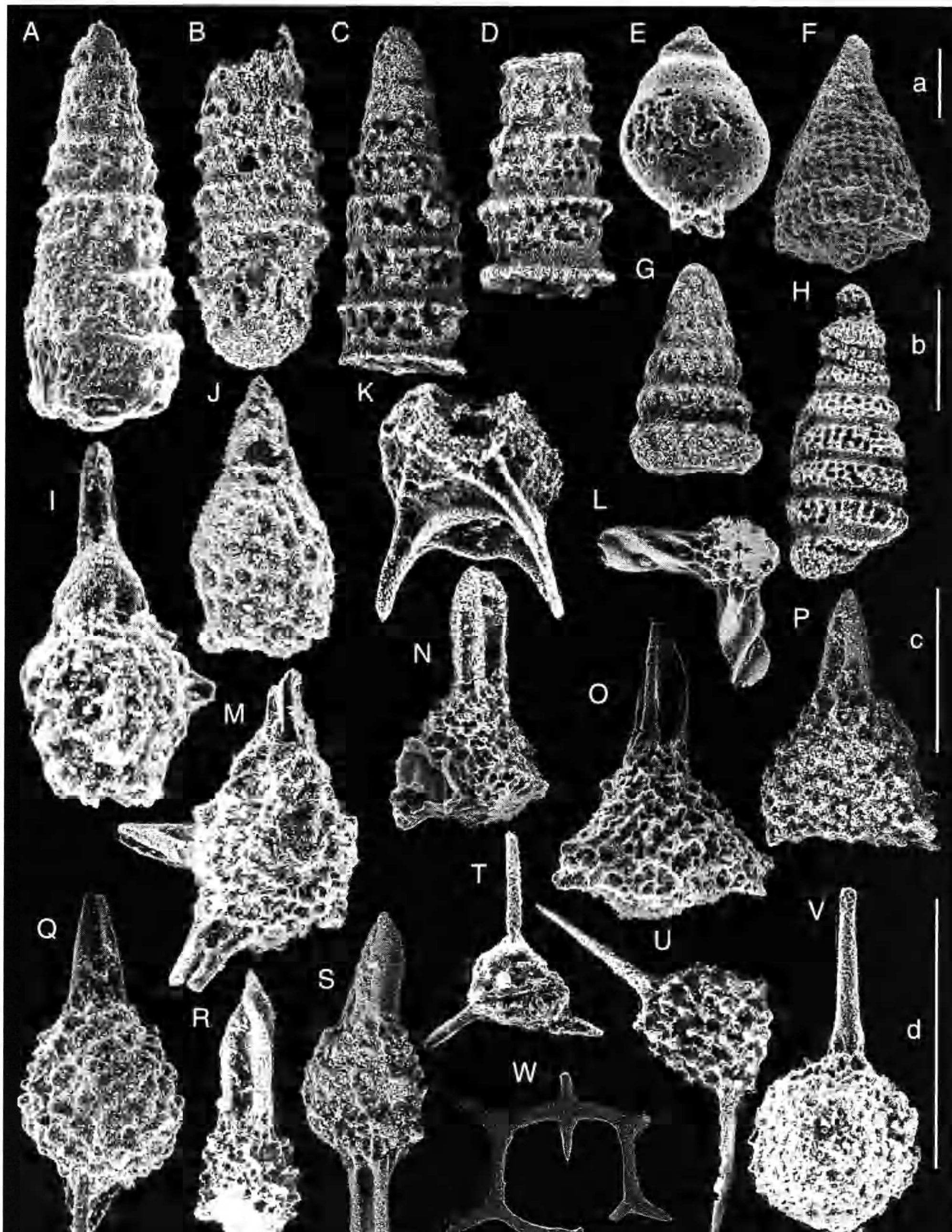

FIG. 5. — Middle-Late Triassic and earliest Jurassic radiolarians from the chert pebbles of the Ryoseki-Monobegawa group in East Shikoku. **A**, *Triassocampe longicephalis* Kozur & Mostler; **B**, *Annulotriassocampe campanilis* Kozur & Mostler; **C**, **D**, *Triassocampe* aff. *scalaris* Dumitrica, Kozur & Mostler; **E**, *Gigi fustis* De Wever; **F**, *Parahsuum simplum* Yao; **G**, *Corum speciosum* Blome; **H**, *Pararuesticyrtium mediotassanicum* Kozur & Mostler; **I**, *Hindedorcus holdsworthi* Sugiyama; **J**, *Theocorys* sp. A of Nakaseko & Nishimura; **K**, *Hozmadia reticulata* Dumitrica, Kozur & Mostler; **L**, *Tiborella cochleata* (Nakaseko & Nishimura); **M**, *Betunella robusta* Dumitrica, Kozur & Mostler; **N**, *Eptingium manfredi robustum* Kozur & Mostler; **O**, *Eptingium nakasekoi* Kozur & Mostler; **P**, *Eptingium* cf. *manfredi* Dumitrica; **Q**, *Pseudostylosphaera spinulosum* (Nakaseko & Nishimura); **R**, *Pseudostylosphaera* sp. C of Kojima & Mizutani, 1987; **S**, *Pseudostylosphaera japonica* (Nakaseko & Nishimura); **T**, *Capnodoce sarisa* De Wever; **U**, *Trilonche japonica* Nakaseko & Nishimura; **V**, *Sarla* (?) *externa* Blome; **W**, *Acanthocircus vigrassi* Blome. Scale bars: 100 µm; **a**, W; **b**, H, L-P, R-V; **c**, A-G, J, K, Q; **d**, I.

larian age. In the marginal area of East Asia and Japanese Islands, Jurassic and pre-Jurassic ACs originate from OPS that are mainly composed of chert-clastic sequences. In these chert-clastic sequences, sediments start from pelagic bedded cherts, and they gradually change upwards towards alternating beds of turbidite sandstones and mudstones (trench-fill turbidite) by way of hemipelagic siliceous mudstone beds.

Regarding the conglomerates in the Lower Cretaceous Ryoseki-Monobegawa group, the following method of processing is used. If gravels are larger than 20 mm in diameter, and it is easy to isolate them from the matrix, gravels of cherts and mudstones are chemically processed separately. If gravels are too small (less than 20 mm in diameter) and difficult to isolate separately from the hard matrix, slabs of conglomerates about 5 mm thick are made. Then, gravels are cut off using pliers. After that, the fragments of pebbles are classified lithologically into cherts or mudstones. In the Ryoseki-Monobegawa group, the matrices of conglomerates are usually composed of sandstones. They contain not only chert clasts but also mudstone grains that are less than 2 mm in diameter. In the study, the matrices of conglomerates are separated from the gravels before processing. This method shows that the matrices yield quite different kind of radiolarians abundantly compared with those from the chert gravels. The samples were processed by 3-7% diluted HF for about 12 hours. The process was repeated several times.

RADIOLARIAN AGE OF GRAVELS AND CLASTS

The chert gravels of chert-pebble conglomerates of the Ryoseki-Monobegawa group yield Middle-Late Triassic, and earliest Jurassic radiolarians (Fig. 5). Among them, *Hindedorcus boldsworthi*, *Eptingium nakasekoi*, *E.* cf. *manfredi*, *Triassocampe* aff. *scalaris*, *Annulotriassocampe campanilis*, *Trilonche japonica*, *Pseudostylosphaera japonica*, *Beturiella robusta*, *Pseudostylosphaera spinulosum*, *P.* sp. C of Kojima & Mizutani (1987), *Triassocampe longicephalis*, *Pararuesticyrtium mediofassanicum*, *Hozumadia reticulata*, *Tiborella cochleata* are characteristic of the Middle Triassic. *Hindedorcus boldsworthi* was reported from the chert beds of the Kinkazan, Mino-Tamba Belt (Sugiyama 1992). This species is characteristic in *Hozmadia gifuensis* assemblage of the early Anisian age. *Eptingium nakasekoi* was reported from the *Paraceratites trinodosus* zone (Illyrian) in the Balaton Hills, Hungary (Kozur & Mostler 1994). *Eptingium* cf. *manfredi* is closely related with the same species that was reported from the bedded chert sequences in the Inuyama area of the Mino-Tamba Belt. The species occurs with *Triassocampe deweveri* and Ladinian conodonts (Yao 1982). *Triassocampe* aff. *scalaris* co-occurs with Anisian conodonts from the chert beds of the South Chichibu Belt (Ishida 1984). *Annulotriassocampe campanilis* was reported from the Fassan beds of the Balaton Hills, Hungary (Kozur & Mostler 1994). *Trilonche japonica* co-occurred with *Triassocampe deweveri* in the chert of the South Chichibu Belt (Nakaseko & Nishimura 1979). *Pseudostylo-sphaera japonica* was described from the chert beds of the South Chichibu Belt (Nakaseko & Nishimura 1979). This species co-occurs with *Neogondolella bulachensis* in the late Anisian-early Ladinian chert beds of the Sikhote-Alin and Sakhalin (Bragin 1991). Another reports on occurrences are from bedded cherts in the Mino-Tamba Belt (Yao 1982) and the Nadanhada, NE China (Kojima & Mizutani 1987). *Beturiella robusta* was reported from the "*Nodosus* bed" about the Anisian/Ladinian boundary in the southern Dolomiten Alps (Dumitrica *et al.* 1980). *Pseudostylosphaera spinulosum* was reported from chert beds of the South Chichibu Belt (Nakaseko & Nishimura 1979), and from the upper Anisian-lower Ladinian chert beds in the northernmost Sakhalin with *Pseudostylosphaera japonica* (Bragin 1991). *Pseudostyloshaera* sp. C of Kojima & Mizutani (1987) has slightly twisted polar spines. This species was reported from the late Anisian to Ladinian bedded chert in the Nadanhada Range. *Triassocampe longicephalis* is described in the early Ladinian (middle Fassanian) beds of the Vincentinian Alps, Italy (Kozur & Mostler 1994). *Pararuesticyrtium mediofassanicum* is known in the *Ladinocampe multiperforata* zone of the middle Fassanian beds in the Vincentinian

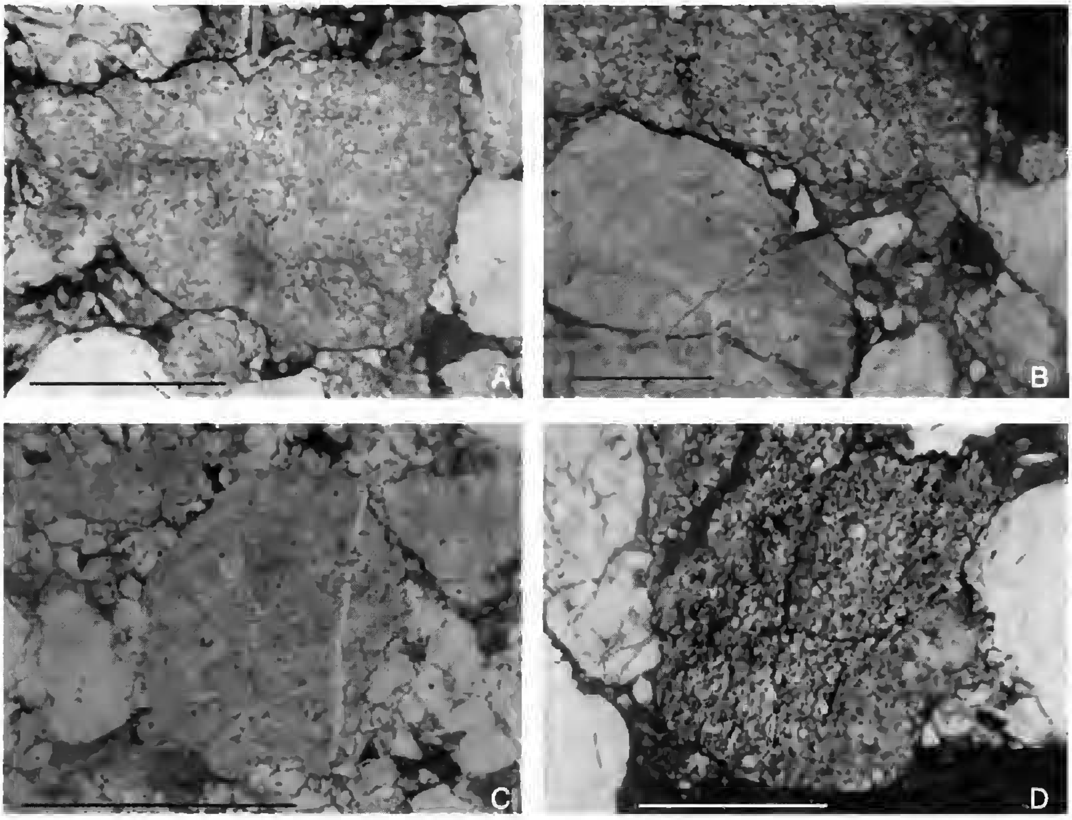

FIG. 6. — Photomicrographs showing clasts (sand sizes) of mudstones (dark) and cherts (light) in the matrix part of the chert-pebble conglomerates. These mudstone clasts contain many radiolarian tests (small round circles). **A-D**, Psammitic matrices of the chert-pebble conglomerates in the Ryoseki-Monobegawa group, East Shikoku. Scale bars: 1 mm.

Alps, Italy (Kozur & Mostler 1994). *Hozumadia reticulata* is reported from the lower Ladinian beds in the Southern Alps (Dumitrica *et al.* 1980). The species is characteristic in *Spongosilicarmiger italicus* zone of the lower Fassanian (Kozur & Mostler 1994). *Tiborella cochleata* is reported with *Triassocampe deweveri* from chert in Inuyama, Mino-Tamba Belt (Nakaseko & Nishimura 1979).

The Upper Triassic radiolarians such as *Capnodoce sarisa*, *Theocorys* sp. A, *Sarla* (?) *externa*, *Acanthocircus vigrassi* and *Corum speciosum* are extracted from chert pebbles. *Capnodoce sarisa* is described from the Upper Triassic formations in Turkey and Sicily (De Wever *et al.* 1979). This species occurs with *Theocorys* sp. A and Carnian conodonts from the gray chert in Shimo-aso of the Mino-Tamba Belt (Nakaseko & Nishimura 1979). *Sarla* (?) *externa* is reported from the upper Carnian (?)-middle Norian beds in Mid-East Oregon (Blome 1983). *Acanthocircus vigrassi* was reported from the Triassic (upper Carnian (?)-middle Norian) Cabin mudstone in East Oregon (Blome 1984). *Corum speciosum* is described from the Rail Cabin mudstone (lower-middle Norian) in Oregon (Blome 1984). *Paleosaturnalis* sp. are extracted with *Sarla* (?) *externa* from a chert pebble in the conglomerate.

Parahsuum simplum and *Gigi fustis* of the earliest Jurassic materials are also found in the other chert gravels. *Parahsuum simplum* is the index species of the *P. simplum* zone (Hori 1990). This species is widely reported from the bedded chert in Mino-Tamba, Ashio, North Chichibu and South Chichibu belts (Yao 1982; Suyari *et al.* 1982; Ishida 1983; Sashida 1988). *Gigi fustis* is reported from the calcareous chert in the lower

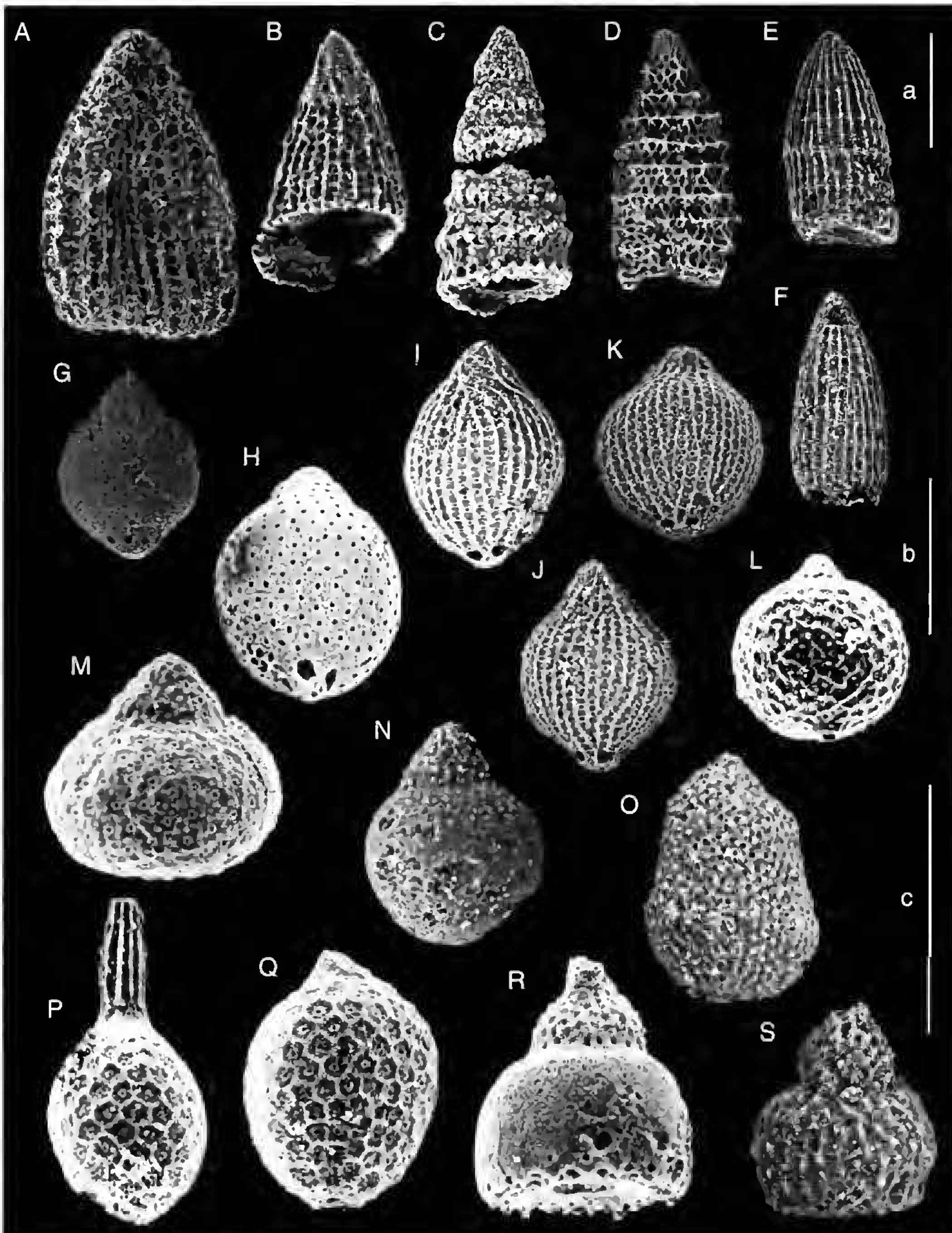

FIG. 7. — Early, Middle and Late Jurassic radiolarians from the small clasts and pebbles of mudstones in the chert-pebble conglomerates of the Ryoseki-Monobegawa group in East Shikoku. **A**, *Parahsuum ovale* Hori & Yao; **B**, *Parahsuum* (?) *grande* Hori & Yao; **C**, *Dictyomitrella kamoensis* Mizutani & Kido; **D**, *Ristola dhimenaensis* (Baumgartner); **E**, **F**, *Archaeodictyomitra suzukii* Aita; **G**, *Tricolocapsa fusiformis* Yao; **H**, *Tricolocapsa* aff. *fusiformis* Yao; **I-K**, *Tricolocapsa plicarum* Yao; **L**, *Tricolocapsa* cf. *ruesti* Tan; **M**, *Stichocapsa japonica* Yao; **N**, *Tricolocapsa* cf. *parvipora* Tan of Yao, **O**, *Theocapsomma cordis* Kocher, **P**, **Q**, *Stylocapsa oblongula* Kocher; **R**, *Eucyrtidiellum unumaensis* (Yao); **S**, *Eucyrtidiellum nodosum* Wakita. Scale bars: 100 µm; a, A, D; **b**, B, C, E-G, I-L; **c**, H, M-S.

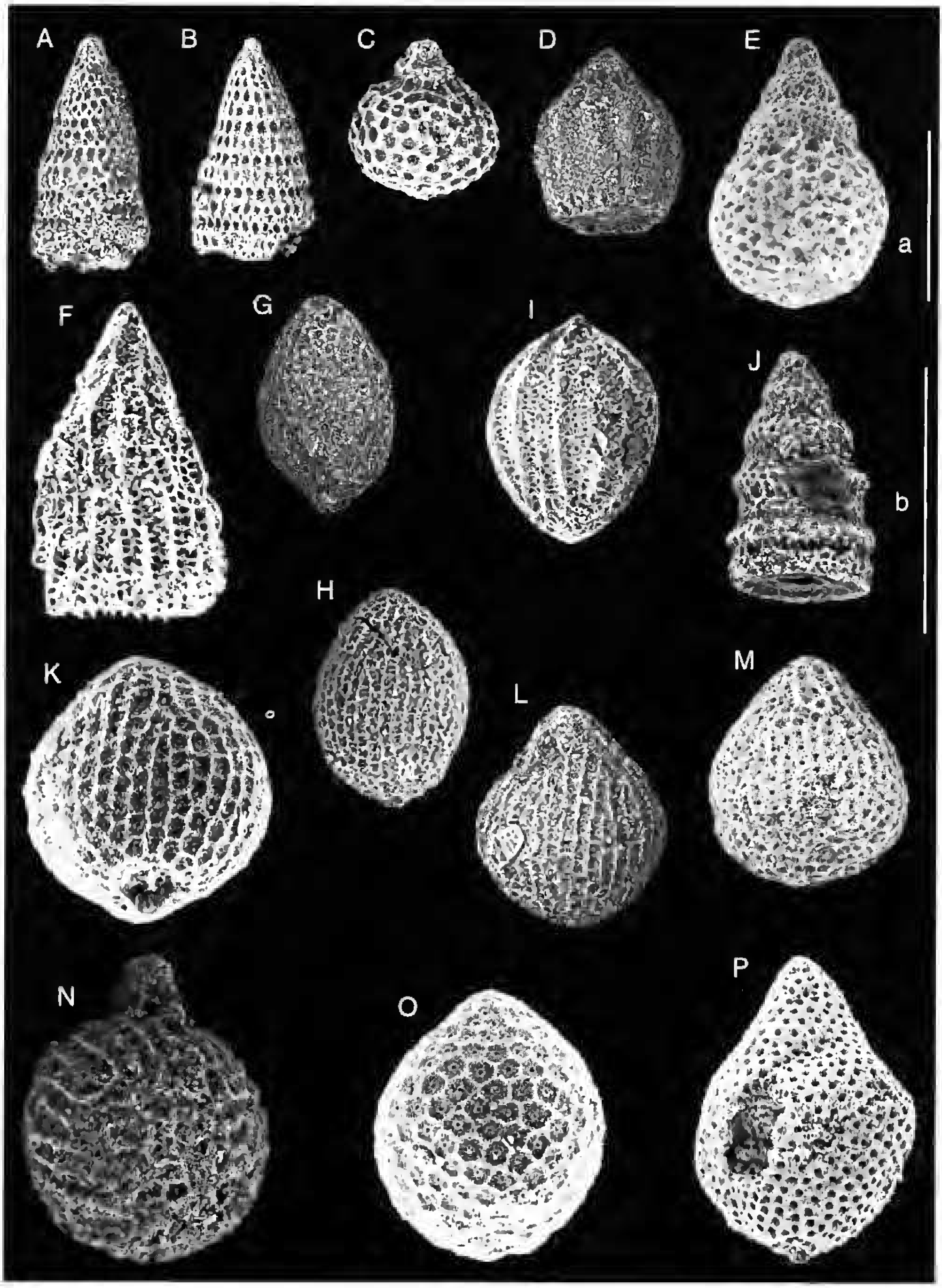

FIG. 8. — Middle-Late Jurassic and earliest Cretaceous radiolarians from the small clasts and pebbles of mudstones in the chert-pebble conglomerates of the Ryoseki-Monobegawa group in East Shikoku. **A**, **B**, *Pseudodictyomitra primitiva* Yao; **C**, *Sethocapsa pseudouterculus* Aita; **D**, *Eucyrtidiellum pyramis* (Aita); **E**, *Sethocapsa horokanaiensis* Kawabata; **F**, *Hsuum maxwelli* Pessagno; **G**, **H**, *Stichocapsa naradaniensis* Matsuoka; **I**, *Protunuma japonicus* Matsuoka & Yao; **J**, *Cinguloturris carpatica* Dumitrica; **K**, **L**, *Tricolocapsa conexa* Matsuoka; **M**, *Stylocapsa lacrimaris* Matsuoka; **N**, *Stylocapsa* (?) *spiralis* Matsuoka; **O**, *Gongylothorax favosus* Dumitrica; **P**, *Stichocapsa robsta* Matsuoka. Scale bars: 100 µm; a, A-J, L, M, P; **b**, K, N, O.

Liassic (Sinemurian-?Pliensbachian) *Budva* zone in the Dinarides, Montenegro (Gorican 1994). The related species co-occur with *P. simplum* from chert in the Katsuyama Section of the Mino-Tamba Belt (Hori 1990).

Matrices of the chert-pebble conglomerates contain many small clasts of mudstones as well as small clasts of cherts. Their diameters are less than 2 mm. Among these mudstone clasts, some are composed of micaceous black mudstones. The others are siliceous mudstones and tuffaceous ones that are usually dark gray or black colored. They commonly contain many radiolarians (Fig. 6). These small clasts of mudstones and some mudstone pebbles in the chert-pebble conglomerates yield the Early Jurassic, Middle-early Late Jurassic, Late Jurassic, and the earliest Cretaceous radiolarians (Figs. 7, 8). Among them, the Early Jurassic materials are *Parahsuum ovale* and *Parahsuum* (?) *grande*. *Parahsuum ovale* has its range in the *Parahsuum simplum* zone. This species is nearly the same age as *P. simplum*, but appears later in the bedded chert sequences of the Mino-Tamba Belt (Hori 1990). This species is also reported from the black mudstone of the North Chichibu Belt in Kyushu, SW Japan (Hori 1990; Miyamoto & Kuwazuru 1993). *Parahsuum* (?) *grande* is the index species of the zone that belongs to the Upper Lower Jurassic (Hori 1990). The Middle-early Late Jurassic materials are *Tricolocapsa plicarum*, *T. fusiformis*, *T.* aff. *fusiformis*, *T. conexa*, *T. parvipora*, *T.* cf. *ruesti*, *Gongylothorax favosus*, *Eucyrtidiellum unumaensis*, *E. nodosum*, *Theocapsomma cordis*, *Dictyomitrella kamoensis*, *Archaeodictyomitra* cf. *suzukii*, *Stichocapsa japonica*, *S. robusta*, *Stylocapsa oblongula*, *Hsuum maxwelli*, *Ristola dhimenaensis*. They are reported from the *Tricolocapsa plicarum* zone and *Tricolocapsa conexa* zone or *Stylocapsa* (?) *spiralis* zone of Matsuoka (1995), and/or *Tricolocapsa tetragona* interval zone (IZ; Callovian)-*Foremanella hipposidericus* zone (Oxfordian) of Aita (1987). For example, *Tricolocapsa conexa* ranges from the *Tricolocapsa tetragona* IZ to the *Foremanella hipposidericus* zone of Aita (1987). It also ranges from the *Tricolocapsa conexa* zone (upper Bathonian) to the *Stylocapsa* (?) *spiralis* zone (Oxfordian) of Matsuoka (1995). This species is regarded to indicate the UA zones 6-15 of Gorican (1994) and the UA zones 4-7 of InterRad J-C WG (1995). These zones are correlated with the late Bajocian to Bathonian or Callovian. *Tricolocapsa parvipora* has its range in the *Tricolocapsa tetragona* IZ-*Amphipyndax tsunoensis* IZ of Aita (1987). This species is regarded to indicate the UA zones 3-5 of Baumgartner (1984), and the UA zones 6-7 (InterRad J-C WG 1995) that are correlated with the late Middle-early Late Jurassic (middle Bathonian to Callovian or early Oxfordian). *Cingulotturris carpatica*, *Stylocapsa lacrimaris*, *Stylocapsa* (?) *spiralis*, *Stichocapsa naradaniensis*, *Protunuma japonicus* are characteristic of the *Stylocapsa* (?) *spiralis* zone-*Cingulotturris carpatica* zone (Lower-middle Upper Jurassic) of Matsuoka & Yao (1985), and the *Stylocapsa* (?) *spiralis* zone-*Hsuum maxwelli* zone (uppermost Callovian-Kimmeridgian) of Matsuoka (1995). The latest Jurassic and earliest Cretaceous materials are *Pseudodictyomitra primitiva*, *Sethocapsa horokanaiensis*, *Sethocapsa pseudouterculus*, *Eucyrtidiellum pyramis*. Among them, *Pseudodictyo-mitra primitiva* is the zone index species (Matsuoka 1995). *Sethocapsa pseudouterculus* and *Eucyrtidiellum pyramis* are characteristic of the lowest Cretaceous *Ditrabs sansalvadorensis* zone (Aita 1986). According to Kawabata (1988), *Sethocapsa horokanaiensis* ranges from the *Tricolocapsa yaoi* assemblage zone (AZ) to the *Pseudodictyomitra primitiva* AZ of Matsuoka & Yao (1985). This species occurred partly with *P. primitiva* or *E. pyramis* in the chert-siliceous mudstone sequences of the Sorachi group.

Other assemblages include Early and Late Permian radiolarians such as *Pseudoalbaillella scalprata* morphotype *postscalprata*, *Follicucullus porrectus*, *F. scholasticus*, *F. charveti*, *Albaillella asymmetrica*, *A. triangularis*, *A. excelsa*, *A.* aff. *levis* and *Nazarovella* sp. (Fig. 9). According to Ishiga (1990), *Pseudoalbaillella scalprata* morphotype *postscalprata* has its range in the upper Lower Permian. *Albaillella asymmetrica* ranges from the upper Lower to lower Middle Permian. The other species have ranges in the Upper Permian *F. scholasticus* zone to the *Neoalbaillella ornithoformis* zone or the *N. optima* zone (Ishiga 1990, 1991). Among them, *Follicucullus scholasticus*, *F. porrectus* and *A. triangularis* are extracted

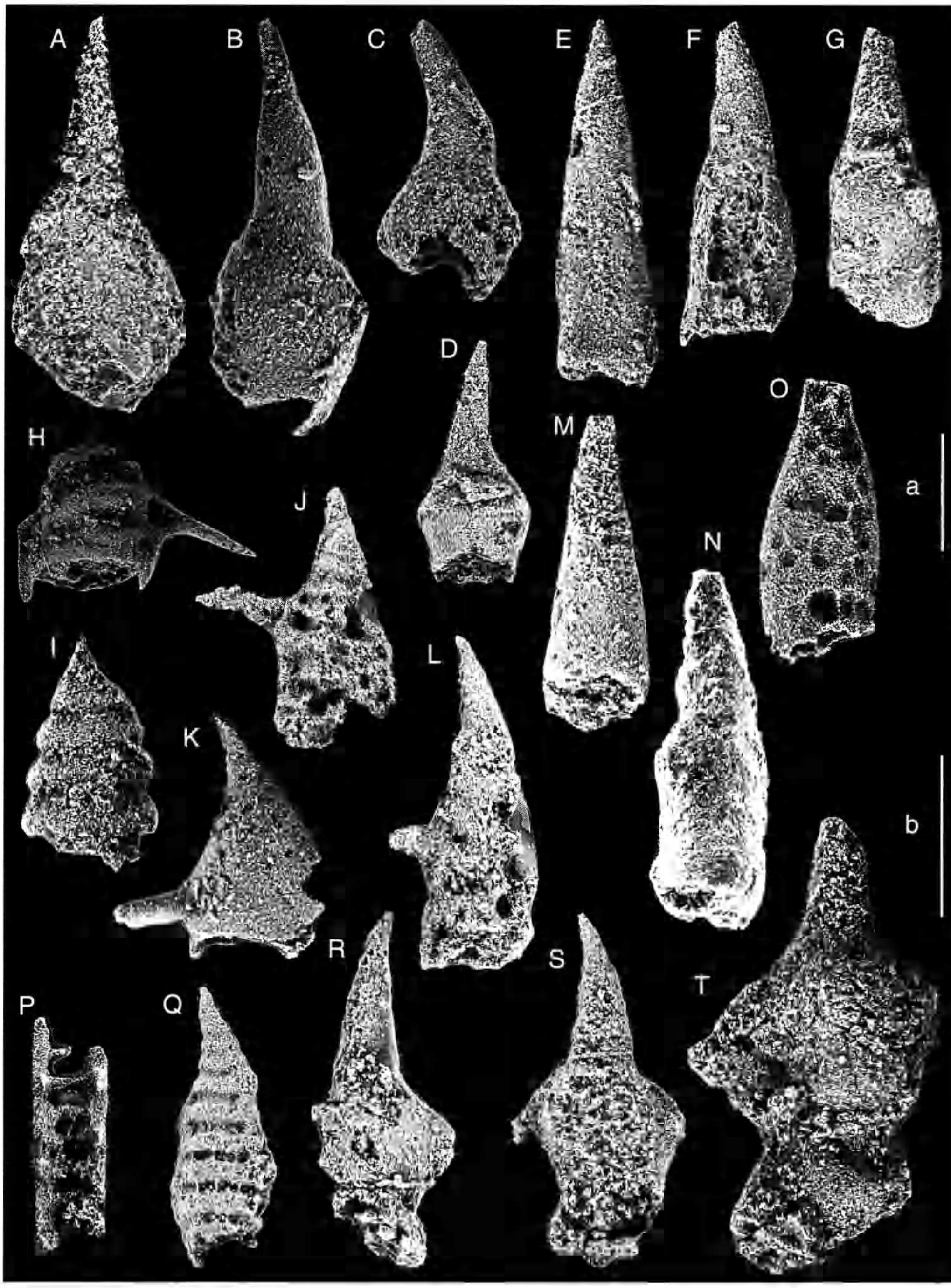

FIG. 9. — Permian radiolarians from the mudstone clasts (A-H) and chert pebbles (I-T) in the chert-pebble conglomerates of the Ryoseki-Monobegawa group in East Shikoku. **A-D**, *Follicucullus charveti* Caridroit & De Wever, every ventral spine below sinus is broken off; **E**, *Follicucullus scholasticus* Ormiston & Babcock.; **F**, **G**, *Follicucullus porrectus* Rudenko; **H-J**, *Albaillella triangularis* Ishiga, Kito & Imoto; **I**, Ventral wing-side view. Ventral wing is broken off; **K**, *Albaillella* aff. *levis* Ishiga Kito & Imoto of Kuwahara, 1997; **L**, *Albaillella excelsa* Ishiga, Kito & Imoto; **M**, *Follicucullus scholasticus* Ormiston & Babcock; **N**, **O**, *Follicucullus porrectus* Rudenko; **P**, *Nazarovella* sp.; **Q**, *Albaillella asymmetrica* Ishiga & Imoto; **R-T**, *Pseudoalbaillella scalprata* morphotype *postscalprata* Ishiga. Scale bars: 100 µm; **a**, D, F-H, N, P, Q; **b**, A-C, E, I-M, O, R-T.

from chert pebbles and mudstone clasts. *Follicucullus charveti* is only extracted from the mudstone clasts, whereas *Pseudoalbaillella scalprata* morphotype *postscalprata*, *Albaillella asymmetrica*, *A. excelsa*, *A.* aff. *levis* and *Nazarovella* sp. are extracted from the chert pebbles.

RECONSTRUCTION AND CORRELATION OF OCEANIC PLATE STRATIGRAPHY

Age determinations on chert and mudstone gravels and fine clasts of mudstones allows a reconstruction of "continuous" stratigraphy ranging from Middle Triassic to the lowest Cretaceous (Fig. 10). The succession reveals a chert-clastic sequence that is usually found in place in the Jurassic AC, with clear lithologic boundary between chert and mudstone just in the *Parahsuum simplum* zone of the Lower Jurassic (Hori 1990; Matsuoka 1995).

In the Chichibu Superterrane, Jurassic AC is distributed both in the South and North Chichibu belts (Fig. 2). They are very close to the studied formations, and have OPSs of chert-clastic sequences. Comparing the OPS of the North Chichibu Belt with the OPS of the South Chichibu Belt, the complex of the North Chichibu Belt was accreted earlier (Fig. 11). The chert facies of the North Chichibu Belt ends in the uppermost Triassic *Canoptum triassicum* zone or the lowest Jurassic *Parahsuum simplum* zone (Suyari, *et al.* 1982; Ishida 1985). On the other side, chert facies of the South Chichibu Belt continues into the Middle Jurassic *Laxtorum* (?) *jurassicum* zone-lower Upper Jurassic *Stylocapsa* (?) *spiralis* zone (Matsuoka 1984, 1996; Ishida 1985, 1987a; Hoshina *et al.* 1995; Isozaki 1997b). The OPS of origin inferred from the gravels is correlative with the OPS of the North Chichibu Belt rather than with the OPS of the South Chichibu Belt (Fig. 11).

Concerning the Permian, two types of geological columns are reconstructed. The first one is composed of chert ranging from the Lower to the Upper Permian. The second one is composed of the Upper Permian mudstone facies characterized by the occurrence of *Follicucullus charveti*. The distribution of *F. charveti* is strictly restricted among the Late Permian faunas. The fauna that includes *F. charveti* is distributed in the Upper-Permian pelitic facies of the Maizuru, Ultra-Tamba and the Kurosegawa belts (Caridroit & De Wever 1986; Ishiga 1990; Isozaki 1997a). Upper Permian mudstone-clasts are probably derived from these belts. On the contrary, Upper Permian cherts are commonly included in the Jurassic AC of the North and South Chichibu belts in the Outer Zone of SW Japan (Fig. 11). In the Inner Zone, they are common in the Jurassic AC of the Mino-Tamba Belt (e.g., Ishiga & Imoto 1980; Kuwahara 1997).

PROVENANCE OF CHERT AND MUDSTONE GRAVELS IN RYOSEKI-MONOBEGAWA GROUP

Among these radiolarian-bearing gravels and clasts, Triassic to Early Jurassic chert pebbles and Early to early Middle Jurassic mudstone clasts are probably derived from the AC of the North Chichibu Belt. On the contrary, the late Middle-Late Jurassic and earliest Cretaceous mudstone clasts are considered to be derived from the equivalents of the Torinosu group (Ishida 1994). The same species of late Middle-Late Jurassic and the earliest Cretaceous radiolarians are common in the Torinosu group. The Torinosu group is upper Middle-Upper Jurassic and lowest Cretaceous open-sea and shallow marine sediments composed of mudstone facies with small amount of sandstones, muddy limestones and conglomerates. The thickness is thinner than 250 m. The Torinosu group is now distributed in the South Chichibu Belt and the south unit of the Kurosegawa Belt where the group unconformably overlies the pre-Jurassic ACs and the Triassic shallow-marine formations (Fig. 11). On one hand, the shallow-marine Triassic formation is never distributed in the north unit of the Kurosegawa Belt nor North Chichibu Belt where the Ryoseki-Monobegawa group unconformably overlies the Permian AC directly. There are large stratigraphic and facies gaps between the Permian AC and the Lower Cretaceous paralic formations in the north unit of the Kurosegawa Belt, whereas the Lower Cretaceous Takegatani

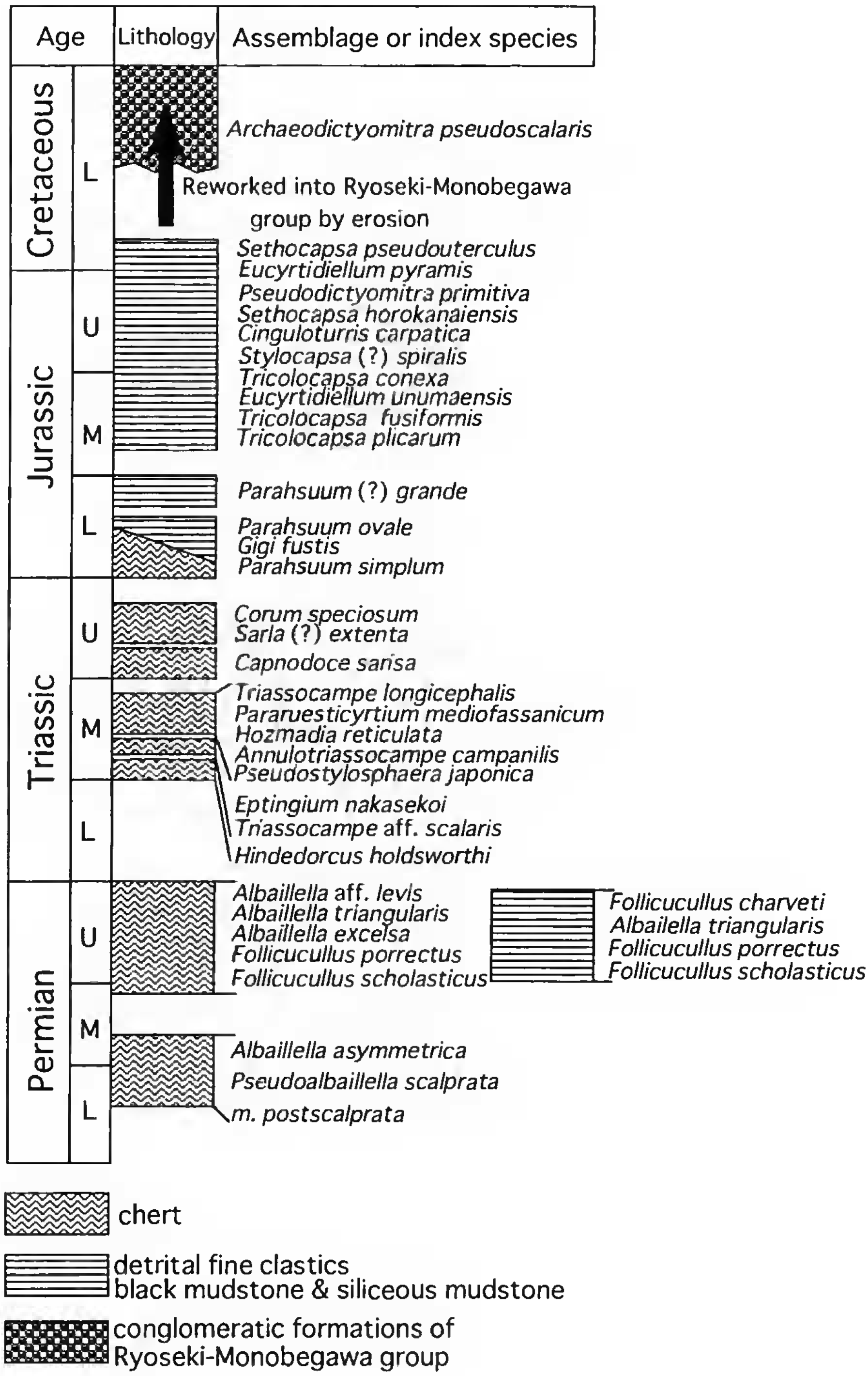

FIG. 10. — Schematic columns showing the oceanic plate stratigraphy of the provenancial terranes. They are inferred from the radiolarian-bearing chert-pebbles and mudstone-clasts in the chert-pebble conglomerates of the Ryoseki-Monobegawa group.

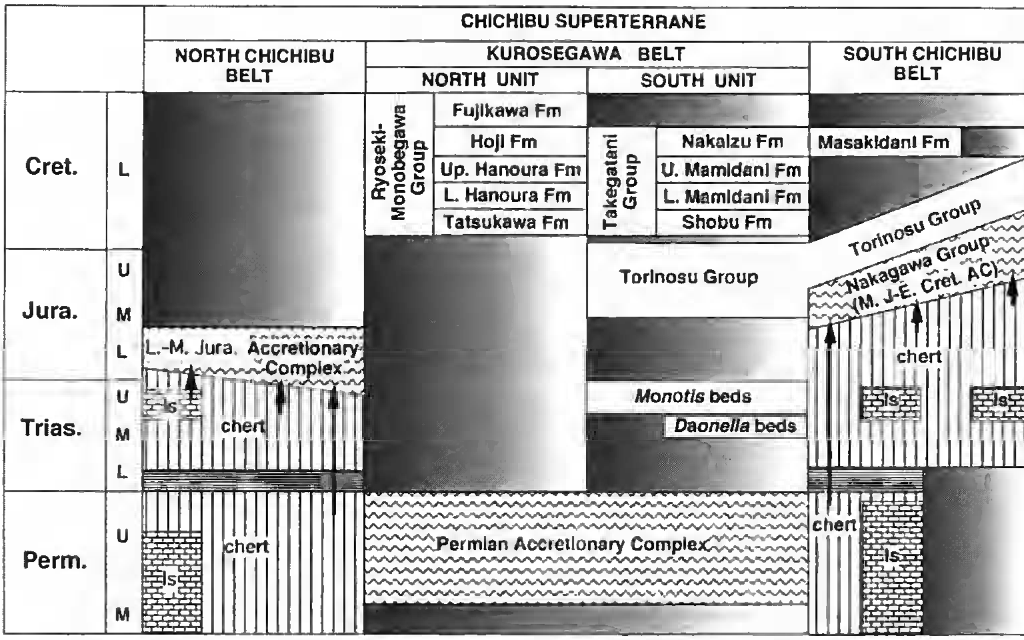

FIG. 11. — Stratigraphy of the upper Paleozoic and Mesozoic formations in the North Chichibu, South Chichibu and Kurosegawa belts in the Chichibu Superterrane, East Shikoku.

group and the Masakidani formation that are equivalent of the Ryoseki-Monobegawa group overlie the Torinosu group in the south unit of the Kurosegawa Belt and the South Chichibu Belt. There are not important stratigraphic gaps nor facial differences among the Torinosu group, Ryoseki-Monobegawa group and its equivalents (Fig. 11).

As a result, the author considers that these chert pebbles probably originated from the chert-clastic sequences and/or complexes of the North Chichibu Belt. It also indicates that the Lower to lower Middle Jurassic ACs of the North Chichibu Belt probably cropped out at the continental side of the Ryoseki-Monobegawa group, and were already eroded in the Early Cretaceous. On one hand, pebbles and small fragments of mudstones containing the Late Middle to Late Jurassic and the earliest Cretaceous radiolarians probably originated from the late Middle Jurassic-earliest Cretaceous cover formations that are the equivalent of the Torinosu group. The equivalents of the Torinosu group were spread widely above the North Chichibu Belt and they were eroded together at the same orogenic event.

PROVENANCE OF ACCOMPANIED FUSULINACEAN-LIMESTONE PEBBLES

In addition to chert pebbles, the conglomerate of the Lower Hanoura formation also contains small gravels of micritic limestones. Limestone gravels usually do not derive from long distances, as river waters usually have acidic chemical conditions. They contain Permian and Carboniferous fusulinids species of *Fusulinella*, *Neoschwagerina* and *Yabeina*. Among them, *N. craticulifera* is characteristic of these micritic limestone gravels. Large blocks of white micrites that contain species of *Neoschwagerina*, *Yabeina* and *Fusulinella* are characteristic in the Jurassic ACs of the North and South Chichibu belts, whereas the *Colania-Lepidolina* bearing muddy limestones are characteristic in the Kurosegawa Belt (Ishii 1990). It suggests that the North Chichibu and the Kurosegawa belts belong to two distinct units. It is also remarkable that the fusulinid-bearing white micrite pebbles are included in the chert-pebble conglomerates. Therefore, these micrite pebbles are probably derived from the limestone blocks of the North

Chichibu Belt. They are transported together with the radiolarian-bearing chert pebbles and mudstone clasts. Based on paleocurrent evidences (Matsukawa & Tsuneoka 1993) and facies analysis (Ishida *et al.* 1992, 1996), sediments of the Ryoseki-Monobegawa group were transported from the northwest to the southeast. The direction of transport is relevant to a potential provenance from the North Chichibu Belt.

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REFERENCES

Aita Y. 1986. — Radiolarian and calcareous nannofossils from the uppermost Jurassic and Lower Cretaceous strata of Japan and Tethyan regions. *Micropaleontoloy*, New York 32: 97-128.

— 1987. — Middle Jurassic to Lower Cretaceous radiolarian biostratigraphy of Shikoku with reference to selected sections in Lombardy basin and Sicily. *Science Reports of Tohoku University, Second Series*, Sendai 58: 1-91.

Baumgartner P. O. 1984. — A Middle Jurassic-Early Cretaceous low latitude radiolarian zonation based on unitary associations and age of Tethyan radiolarites. *Eclogae Geologicae Helveticae*, Basel 77: 729-837.

Blome C. D. 1983. — Upper Triassic Capnuchosphaeridae and Capnodocinae (Radiolaria) from east-central Oregon. *Micropaleontology*, New York 29: 11-49.

— 1984. — Upper Triassic radiolaria and radiolarian zonation from western North America. *Bulletin of American Paleontology*, New York 85 (318): 1-88.

Bragin N. J. 1991. — Radiolaria and Lower Mesozoic units of the USSR, East Regions. *Transactions of the Academy of Sciences of the USSR*, Moscow 469, 122 p. [in Russian].

Caridroit M. & De Wever P. 1986. — Some Late Permian radiolarians from pelitic rocks of the Tatsuno formation (Hyogo Prefecture), Southwest Japan. *Marine Micropaleontology*, Amsterdam 11: 55-90.

Cordey F. 1992. — Radiolarians and terrane analysis in the Canadian Cordillera: the "clastic approach". *Palaeogeography, Palaeontology, Palaeoecology*, Amsterdam 96: 155-159.

De Wever P., Sanfilippo A., Riedel W. R. & Gruber B. 1979. — Triassic radiolaria from Greece, Sicily and Turkey. *Micropaleontology*, New York 25: 75-110.

Dumitrica P., Kozur H. & Mostler H. 1980. — Contribution to the radiolarian fauna of the Middle Triassic of the Southern Alps. *Geologische Palaeontologische Mitteilungen Innsbruck*, Innsbruck 10:1-46.

Faure M. 1983a. — The Mesozoic orogeny in the Outer Zone of SW Japan in eastern Shikoku. *Journal of Gakugei, University of Tokushima*, Tokushima 34: 1-35.

— 1983b. — The pre-Cretaceous structure of the Outer Belt of Southwest Japan. *Tectonophysics*, Amsterdam 113: 139-162.

— 1985. — Microtectonic evidence for eastward ductile shear in the Jurassic orogen of SW Japan. *Journal of Structural Geology*, London 7 (2): 175-186.

Faure M., Caridroit M. & Charvet J. 1986 — The late Jurassic oblique collisional orogen of SW Japan. New structural data and synthesis. *Tectonics*, Washington D.C. 5 (7): 1089-1114.

Faure M., Iwasaki M., Ichikawa K. & Yao A. 1991. — The significance of Upper Jurassic radiolarians in high pressure metamorphic rocks of SW Japan. *Journal of SE Asian Earth Sciences*, Great Britain 6 (2): 131-136.

Gorican S. 1994. — Jurassic and Cretaceous radiolarian biostratigraphy and sedimentary evolution of the *Budva* zone (Dinarides, Montenegro). *Mémoires de Géologie*, Lausanne 18 :1-177.

Hada S. & Kurimoto C. 1990. — Northern Chichibu Terrane. *in* Ichikawa K. *et al.* (eds), Pre-Cretaceous terranes of Japan, *Publication of IGCP Project: Pre-Jurassic evolution of eastern Asia*, Osaka 224: 165-183.

Hori R. 1990. — Lower Jurassic radiolarian zones of SW Japan. *Transactions and Proceedings of the Paleontological Society of Japan*, New Series, Tokyo 159: 562-586.

Hoshina H., Kurimoto T., Makimoto H., Matsuoka K., Sakai A., Sekine K. & Takeuchi K. 1995. — The results of recent researches on the Paleo-Mesozoic of the Kanto Mountains, central Japan. *Earth Science (Chikyu Kagaku)*, Matsumoto 49: 271-291 [in Japanese with English abstract].

Ichikawa K., Ishii K., Nakagawa C., Suyari K. & Yamashita N. 1953 — On "Sakashu-unconformity". *Journal of Gakugei, Tokushima University (Natural Sciences)*, Tokushima 3: 61-74 [in Japanese with English abstract].

InterRad Jurassic-Cretaceous Working Group. Baumgartner P. O. *et al.* (eds) 1995. — Middle Jurassic to Lower Cretaceous radiolaria of Tethys: Occurrences, Systematics, Biochronology, Environments. *Mémoires de Géologie*, Lausanne 23: 1-900.

Ishida K. 1983. — Stratigraphy and radiolarian assemblages of the Triassic and Jurassic siliceous sedimentary rocks in Konose valley, Tokushima prefecture, Southwest Japan. *Journal of Science, University of Tokushima*, Tokushima 16: 111-141 [in Japanese with English abstract].

— 1984. — The order of appearance of some radiolarians in Anisian bedded-chert bodies in the South Zone of the Chichibu Belt, eastern Shikoku. *Journal of Science, University of Tokushima*, Tokushima 17: 15-29 [in Japanese with English abstract].

— 1985. — Pre-Cretaceous sediments in the southern North zone of the Chichibu Belt in Tokushima prefecture, Shikoku. *Journal of Geological Society of Japan*, Tokyo 91 (9): 553-567 [in Japanese with English abstract].

— 1987. — Geology and microbiostratigraphy of the Southern Chichibu Terrane in eastern Shikoku, Southwest Japan. *Journal of Science, University of Tokushima*, Tokushima 2: 47-121 [in Japanese with English abstract].

— 1994. — Radiolarians from the shallow marine Lower Cretaceous of the Kurosegawa Terrane, East Shikoku: a distinctive key marker for the paleoenvironmental changes. *Seventh meeting of the International Association of Radiolarian Paleontologists*, (Abstracts), Osaka: 56

Ishida K. & Hashimoto H. 1991a. — Radiolarian assemblages from the Lower Cretaceous formations of the Chichibu Terrane in eastern Shikoku and their ammonite ages. *Journal of Science, University of Tokushima*, Tokushima 25: 23-67 [in Japanese with English abstract].

Ishida K., Hashimoto H. & Kozai T. 1992. — Litho- and bio-stratigraphy of the Lower Cretaceous Hanoura formation in East Shikoku. Part 1. Hiura and Tsukigatani routes in Katsuura-gawa area. *Journal of Science, University of Tokushima*, Tokushima 26: 1-57 [in Japanese with English abstract].

— 1996. — Litho- and bio-stratigraphy of the Lower Cretaceous Hanoura formation in East Shikoku. Part 2. Study of the Lower Cretaceous formations of the Hanoura Hill. *Natural Science Research of University of Tokushima*, Tokushima 9: 23-47 [in Japanese with English abstract].

Ishiga H. 1986. — Late Carboniferous and Permian radiolarian biostratigraphy of Southwest Japan. *Journal of Geoscience, Osaka City University*, Osaka 29: 89-100.

— 1990. — Paleozoic radiolarians, *in* Ichikawa K. *et al.* (eds), Pre Cretaceous Terranes of Japan, *Publication of IGCP Project: Pre-Jurassic Evolution of Eastern Asia*, Osaka 224: 285-295.

— 1991. — Description of a new *Follicucullus* species from Southwest Japan. *Memoires of Faculty of Science, Shimane University*, Matsue 25: 107-118.

Ishiga H. & Imoto N. 1980. — Some Permian radiolarians in the Tamba district, Southwest Japan. *Earth Science (Chikyu Kagaku)*, Tokyo 34: 333-345.

Ishii K. 1990. — Provinciality of some fusulinacean faunas of Japan, *in* Ichikawa K. *et al.* (eds), Pre-Cretaceous terranes of Japan, *Publication of IGCP Project: Pre-Jurassic Evolution of Eastern Asia*, Osaka 224: 297-305.

Isozaki Y. 1997a. — Contrasting two types of orogen in Permo-Triassic Japan: Accretionnary versus collisional. *The Island Arc*, Carlton South Victoria 6 (1): 2-24.

— 1997b. — Jurassic accretion tectonics of Japan. *The Island Arc*, Carlton South Victoria 6 (1): 25-51.

Isozaki Y., Hashiguchi T. & Itaya T. 1992. — The Kurosegawa klippe: an examination. *Journal of Geological Society of Japan*, Tokyo 98 (10): 917-941.

Kawabata K. 1988. — New species of latest Jurassic and earliest Cretaceous radiolarians from the Sorachi group in Hokkaido, Japan. *Bulletin of Osaka Museum of Natural History*, Osaka 43: 1-13.

Kojima S. & Mizutani S. 1987. — Triassic and Jurassic radiolaria from the Nadanhada range, Northeast China. *Transactions and Proceedings of the Palaeontological Society of Japan*, New Series, Tokyo 148: 256-275.

Kozai T. 1996. — *Lower Cretaceous formations and sedimentary environments in the Ryoseki-Monobegawa area, Kochi prefecture, SW Japan.* Ph. D. Thesis of the Pacific Western University, Los Angeles: 1-79.

Kozur H. & Mostler H. 1994. — Anisian to middle Carnian radiolarian zonation and description of some stratigraphically important radiolarians. *Geologische und Palaeontologische Mitteilungen Innsbruck*, Innsbruck 3: 39-255.

Kuwahara K. 1997. — Evolutionary patterns of Late Permian *Albaillella* (Radiolaria) as seen in bedded chert sections in the Mino Belt, Japan. *Marine Micropaleontology*, Amsterdam 30: 65-78.

Matsukawa M. & Eto F. 1987. — Stratigraphy and sedimentary environment of the Lower Cretaceous system in the Katsuuragawa basin, Southwest Japan. Comparison of the Cretaceous subbelts in the Chichibu Belt. *Journal of Geological Society of Japan*, Tokyo 93 (7): 491-511 [in Japanese with English abstract].

Matsukawa M. & Tsuneoka T. 1993. — Sedimentary environments and paleogeography of the Lower Cretaceous in Southwest Japan based on paleobiogeography of ammonites and dinosaurs. *Memoirs of Geological Society of Japan*, Tokyo 42: 151-165 [in Japanese with English abstract].

Matsuoka A. 1984. — Togano group of the Southern Chichibu Terrane in the western part of Kochi prefecture, southwest Japan. *Journal of Geological Society of Japan*, Tokyo 90: 455-477 [in Japanese with English abstract].

— 1995. — Jurassic and lower Cretaceous radiolarian zonation in Japan and in the western Pacific. *The Island Arc*, Carlton South Victoria 4: 140-153.

— 1996. — Correlation between the Sambagawa metamorphic rocks and non-metamorphic accretionary complexes based on paleontological data: 78-85 [in Japanese with English abstract], *in* Shimamoto T. *et al.* (eds), *Tectonics and Metamorphism*. Soubun Co. Ltd., Tokyo.

Matsuoka A. & Yao A. 1985. — Latest Jurassic radiolarians from the Torinosu group in Southwest Japan. *Journal of Geoscience of Osaka City University*, Osaka 28: 125-145.

— 1986. — A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleontology*, Amsterdam 11: 91-106.

Mizutani S. 1995 — Mesozoic evolution of Japanese Islands, *in* Chang K.-H. (ed.), Environmental and tectonic history of East and South Asia with emphasis on Cretaceous correlation (IGCP 350), *Proceedings of 15th International Symposium of Kyungpook National University*, Taegu: 11-41.

Miyamoto T. & Kuwazuru J. 1993. — Findings of Early Jurassic radiolarians from the Hashirimizu formation at the Hikawa valley, Kumamoto prefecture, Kyushu and its geological significance. *in* Yao A. (ed.), *Proceedings of 4th Radiolarian Symposium, News of Osaka Micropaleontologists*, Special Volume, Osaka 9: 165-175.

Nakaseko K. & Nishimura A. 1979. — Upper Triassic radiolaria from Southwest Japan. *Science Report of College of General Education Osaka University*, Osaka 28: 61-109.

Sashida K. 1988. — Lower Jurassic multisegmented Nassellaria from the Itsukaichi area, western part of Tokyo Prefecture, Central Japan. *Science Report of Institute of Geosciences*, University of Tsukuba, Section B, Tsukuba 9: 1-27.

Sciders V. M. & Blome C. D. 1984. — Clast component of Upper Mesozoic conglomerates of the California Coast Ranges and their tectonic significance, *in* Blake M. C. Jr. (ed.), Franciscan Geology of Northern California, *Society of Economic Paleontologists and Mineralogists, Pacific Section*, Bakesfield 43: 135-148.

— 1988. — Implications of upper Mesozoic conglomerate for suspect terrane in western California and adjacent areas. *Geological Society of America, Bulletin*, Boulder 100: 374-391.

Sugiyama K. 1992. — Lower and Middle Triassic radiolarians from Mt. Kinkazan, Gifu prefecture, central Japan. *Transactions and Proceedings of Paleontological Society of Japan*, New Series, Tokyo 167: 1180-1223.

Suyari K., Kuwano Y. & Ishida K. 1980. — Discovery of late Triassic conodonts from the Sambagawa metamorphic belt proper in Western Shikoku. *Journal of Geological Society of Japan*, Tokyo 86: 827, 828 [in Japanese with English abstract].

— 1982. — Stratigraphy and geological structure of the Mikabu greenrock terrain and its environments. II. Some information about the Mesozoic stratigraphy of the North subbelt of the Chichibu Belt. *Journal of Science, University of Tokushima*, Tokushima 15: 51-71 [in Japanese with English abstract].

Suzuki H. & Itaya T. 1994. — Accretionary complexes of the Kurosegawa, northern Chichibu and Sanbagawa belts in the Kamikatsu town area (Shikoku), Southwest Japan. *Journal of Geological Society of Japan*, Tokyo 100 (8): 585-599 [in Japanese with English abstract].

Taira A., Saito Y. & Hashimoto M. 1981. — Fundamental process in formation of the Japanese Islands. Oblique subduction of plates and strike-slip movement. *Kagaku*, Tokyo 51: 508-515 [in Japanese].

Tashiro M. 1986. — Paleobiogeography and paleoecology of the Cretaceous System of Southwest Japan. *Fossils*, Tokyo 41: 1-16 [in Japanese].

Tashiro M. & Kozai T. 1991. — Bivalve fossils from the type Monobegawa group (Part V). *Research Report of Kochi University*, Kochi 40: 189-204.

Tazawa J. 1993. — Pre-Neogene tectonics of the Japanese Islands from the viewpoint of paleobiogeography. *Journal of the Geological Society of Japan*, Tokyo 99 (7): 525-543 [in Japanese with English abstract].

Yao A. 1982. — Middle Triassic to early Jurassic radiolarians from the Inuyama area, Central Japan. *Journal of Geoscience of Osaka City University*, Osaka 25: 53-70.

— 1990. — Triassic and Jurassic radiolarians, *in* Ichikawa K. *et al.* (eds), Pre-Cretaceous Terranes of Japan, *Publication of IGCP Project: Pre-Jurassic Evolution of Eastern Asia*, Osaka 224: 329-345.

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